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(54) Title: THERAPEUTIC DELIVERY OF CARBON MONOXIDE

(57) Abstract: Metal carbonyls are used in combination with at least one guanylate cyclase stimulant/stabilizer to deliver CO having biological activity, for example vasodilatation and inhibition of platelet aggregation. The two components may be administered simultaneously or sequentially. A particular described combination is tricarbonylchloro(glycinato)ruthenium(II) and the drug YC-1.

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Therapeutic Delivery of Carbon MonoxideFIELD OF THE INVENTION

5 The present invention relates to pharmaceutical preparations, particularly preparations for therapeutic delivery of carbon monoxide to humans and other mammals, to methods of delivery of therapeutic agents and to kits for this purpose.

10

BACKGROUND OF THE INVENTION

The vasodilatory effects of nitric oxide (NO) and carbon monoxide (CO) gases have been known for some time (3). The L-arginine/NO synthase pathway present in the  
15 vascular endothelium plays a fundamental role in the control of vessel relaxation and arterial blood pressure in mammals (4). Increased generation of carbon monoxide (CO) following activation of the heme oxygenase-1 enzyme in the vascular tissue also results in suppression of  
20 acute hypertension *in vivo* (6) and prevention of vasoconstriction *ex vivo* (7).

Most recently, it has been reported that a series of transition metal carbonyls can be utilized as CO-releasing molecules (CO-RMs) in biological systems to  
25 elicit vasorelaxation and prevent increases in blood pressure (5).

Vascular relaxation by NO and CO appears to involve an increase in intracellular cyclic 3',5'-guanosine monophosphate (cGMP) levels through activation of a  
30 soluble heme-dependent guanylate cyclase (sGC) (3; 6; 7). However, it is known that CO is a poor stimulator of sGC in *in vitro* studies when compared to NO; the enzymatic activity of purified guanylate cyclase is increased 130-

fold and 4.4-fold by its interaction with NO and CO, respectively (8).

Interestingly, data from the literature reveal that the catalytic rate of sGC can be substantially improved  
5 by the benzyl-indazole derivative 3-(5'-hydroxymethyl-2'-furyl)-1-benzyl-indazole (YC-1). The mechanism underlying YC-1 action may be the stabilization of guanylate cyclase in its active conformation. It has also been suggested that YC-1 may stimulate production of  
10 guanylate cyclase.

WO02/092075, published 21 November 2002 and originating from work of the present inventors, discloses various metal carbonyl compounds that can be used in the delivery of carbon monoxide to body cells and tissue.  
15 Some of the metal carbonyl compounds disclosed therein typically included a ligand other than CO and can be employed in the present invention. There is a statement that YC-1 may be used as a ligand.

## 20 SUMMARY OF THE INVENTION

An object of the present invention is to provide method of achieving improved therapeutic effects by delivery of carbon monoxide to the human or other mammal body.

25 As exemplified by the experimental data detailed below, the present inventors have found that metal carbonyl compounds can be used in combination with a guanylate cyclase stimulant or stabilizer so as to provide an improved physiological effect.

30 Accordingly, in a first aspect, the present invention provides a pharmaceutical preparation, comprising a metal carbonyl compound or pharmaceutically acceptable salt thereof, a guanylate cyclase stimulant or

stabilizer and at least one pharmaceutically acceptable carrier. Typically the metal carbonyl makes available CO suitable for physiological effect, for delivery of carbon monoxide to a physiological target.

5       The preparation may contain the metal carbonyl and guanylate cyclase stimulant/stabilizer in a single composition, or the two components may be formulated separately for simultaneous or sequential administration.

10       In a second aspect, the present invention provides a method of a therapeutic agent to a mammal comprising the step of administering a pharmaceutical preparation according to the first aspect.

15       In a third aspect, the present invention provides a method of introducing therapeutic agent to a mammal, comprising:

- a) administering a metal carbonyl; and
- b) administering a guanylate cyclase stimulant or stabiliser.

20       The metal carbonyl and guanylate cyclase stimulant/stabilizer may be administered simultaneously either in a single composition or in two separate compositions. The metal carbonyl and stimulant/stabilizer may be administered sequentially. Preferably, the stabilizer/stimulant is administered first followed by the metal carbonyl but this order may be reversed.

25       In a fourth aspect, the invention provides a kit comprising a) a metal carbonyl compound and b) a guanylate cyclase stimulant/stabilizer.

30       The two components may be for administration simultaneously or sequentially.

While the invention is primarily here discussed as involving the delivery of carbon monoxide to a

physiological target wherein the metal carbonyl makes CO available for physiological effect, it is not excluded that a different mechanism is involved, such as that the metal carbonyl acts directly without release of CO.

5       The various aspects of this invention are useful for treating a variety of body tissues in a living mammal. Additionally, isolated organs, e.g. extracorporeal organs or in situ organs isolated from the blood supply, can be treated. The organ may be, for example, a circulatory  
10   organ, respiratory organ, urinary organ, digestive organ, reproductive organ, neurological organ, muscle or skin flap or an artificial organ containing viable cells. In particular, the organ may be a heart, lung, kidney or liver. However, the body tissue which is treatable are  
15   not limited and may be any human or mammal body tissue whether extracorporeal or in situ in the animal body.

      The various aspects of the present invention are used to provide a physiological effect, e.g. for stimulating neurotransmission or vasodilation, or for  
20   treatment of any of hypertension, such as acute, pulmonary and chronic hypertension, radiation damage, endotoxic shock, inflammation, inflammatory-related diseases such as asthma and rheumatoid arthritis, hyperoxia-induced injury, apoptosis, cancer, transplant  
25   rejection, arteriosclerosis, post-ischemic organ damage, myocardial infarction, angina, haemorrhagic shock, sepsis, penile erectile dysfunction, adult respiratory distress syndrome and inhibition of platelet aggregation.

      The various aspects can also be used for perfusion,  
30   of a viable mammalian organ extracorporeally, e.g. during storage and/or transport of an organ for transplant surgery or treatment of an organ which is in the body but is temporarily isolated from the bloodstream, e.g. during

surgery. For this purpose, the metal carbonyl is in dissolved form, preferably in an aqueous solution.

In the various aspects of the present invention, preferably, the metal carbonyl makes CO available by at least one of the following means:

- 1) CO derived by dissociation of the metal carbonyl is present in the composition in dissolved form;
- 2) on contact with a solvent or ligand the metal carbonyl releases CO;
- 3) on contact with a tissue, organ or cell the metal carbonyl releases CO;
- 4) on irradiation the metal carbonyl releases CO.

The most preferred metal carbonyls are water soluble metal carbonyls.

Certain metal carbonyl compounds are capable of releasing CO on contact with a suitable solvent. When the metal carbonyl component is to be administered in liquid form, this solvent may form a part of the component. Thus, the pharmaceutical preparation contains CO derived from the metal carbonyl in dissolved form. The conditions under which the carbonyl compound is dissolved in the solvent during preparation of the metal carbonyl component may be controlled such that the CO thus released is retained in solution. This may be facilitated where an equilibrium exists between the dissociated components and the undissociated carbonyl.

The dissociated components of the parent carbonyl may themselves be metal carbonyl complexes capable of releasing further CO. For example, when  $[\text{Ru}(\text{CO})_3\text{Cl}_2]_2$  is dissolved in DMSO, CO is liberated into solution, and a mixture of tri-carbonyl and di-carbonyl complexes is formed, and these themselves may be capable of releasing further CO.

Alternatively, the metal carbonyl component may not itself contain dissolved CO, but may be prepared such as to release CO on contact with a suitable solvent or medium. For example, the composition may contain a metal carbonyl compound capable of releasing CO on contact with water, e.g. on contact with an aqueous physiological fluid, such as blood or lymph. The metal carbonyl compound may also release CO on contact with perfluorocarbon type blood substitute fluids or on contact with cardioplegic fluid.

Alternatively, the pharmaceutical composition may be intended to be dissolved in water prior to administration. Such metal carbonyl components may be prepared in solution or in solid form, such as in tablet form. If they are in solution form, they will typically be prepared in a solvent which does not support dissociation of the metal carbonyl compound, such that release of CO takes place only on contact with the appropriate substance.

Alternatively or additionally, release of CO from the carbonyl can be stimulated by reaction with a ligand in solution which for example replaces one of the ligands of the complex leading to loss of CO from the complex. The ligand may be one containing sulphur or nitrogen. Some metal carbonyls may release CO on contact with biological ligands such as glutathione or histidine.

As another alternative, the metal carbonyl component may contain a metal carbonyl compound which releases CO on contact with a tissue, organ or cell. It is known that certain metal carbonyl compounds do not release CO to solution but are nevertheless capable of releasing CO to physiological cellular materials or tissues, such as vascular endothelium. For example,  $[\text{Fe}(\text{SPh})_2(2,2'-$

bipyridine) (CO)<sub>2</sub>] does not release CO to myoglobin in solution, but is nevertheless capable of promoting dilatation of pre-contracted aortic rings. Without wishing to be limited by any particular theory, it is  
5 thought that CO may be released from such compounds as a result of an oxidation-reduction reaction, mediated by cellular components such as cytochromes.

However the invention is not limited to a redox reaction as a mechanism for CO release, since loss of at  
10 least a first CO molecule from the complex may occur without redox.

As yet another alternative, the metal carbonyl component may contain a metal carbonyl compound which releases CO on irradiation. The compound may be  
15 irradiated prior to administration, for example to produce a solution of dissolved CO, or may be irradiated *in situ* after administration. It is contemplated that such compositions may be used to provide controlled, localised release of CO. For example a pharmaceutical  
20 composition of this type may be administered during surgery, and CO released specifically at a site in need thereof, e.g. to induce vasodilation, by localised irradiation by means of a laser or other radiant energy source, such as UV rays.

25 Typically the metal carbonyl components of the present invention release CO such as to make it available to a therapeutic target in dissolved form. However, in some circumstances CO may be released from a metal carbonyl directly to a non-solvent acceptor molecule.

30 Typically the metal carbonyl compound comprises a complex of a transition metal, preferably a transition metal from group 6 to 10 (in this specification the groups of the periodic table are numbered according to



the IUPAC system from 1 to 18). The number of carbonyl ligands is not limited, provided at least one carbonyl ligand is present. The preferred metals are transition metals of lower molecular weight, in particular Fe, Ru, Mn, Co, Ni, Mo and Rh. Two other metals which may be used are Pd and Pt. In the metal carbonyl complexes used in the invention, the metal is typically in a low oxidation state, i.e. 0, I or II. For the metals preferred, the oxidation states are typically not higher than Fe<sup>II</sup>, Ru<sup>II</sup>, Mn<sup>I</sup>, Co<sup>II</sup> preferably Co<sup>I</sup>, Rh<sup>III</sup> preferably Rh<sup>I</sup>, Ni<sup>II</sup>, Mo<sup>II</sup>. The metal is preferably not a radionuclide. Fe is one particularly suitable metal, since Fe is present in quantity in mammals.

The metal carbonyl compounds may be regarded as complexes, because they comprise CO groups coordinated to a metal centre. However the metal may be bonded to other groups by other than coordination bonds, e.g. by ionic or covalent bonds. Thus groups other than CO which form part of the metal carbonyl compound need not strictly be "ligands" in the sense of being coordinated to a metal centre via a lone electron pair, but will be referred to herein as "ligands" for ease of reference.

Thus, the ligands to the metal may all be carbonyl ligands, as e.g. in [Mn<sub>2</sub>(CO)<sub>10</sub>]. Alternatively, the carbonyl compound may comprise at least one modulatory ligand. By this is meant a ligand which is not CO, but which modulates a particular property of the complex, such as the tendency to release CO, solubility, hydrophobicity, stability, electrochemical potential, etc. Thus suitable choices of ligand may be made in order to modulate the behaviour of the compound. For example it may be desirable to modulate the solubility of the compound in organic and/or aqueous solvents, its

ability to cross cell membranes, its rate of release of CO on contact with a particular solvent or cell type, or on irradiation, etc.

Such ligands are typically neutral or anionic  
5 ligands, such as halide, or derived from Lewis bases and having N, P, O, S or C as the coordinating atom(s). Preferred coordinating atoms are N, O and S. Examples include, but are not limited to, sulfoxides such as dimethylsulfoxide, natural and synthetic amino acids and  
10 their salts for example, glycine, cysteine, and proline, amines such as  $\text{NEt}_3$  and  $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ , aromatic bases and their analogues, for example, bi-2,2'-pyridyl, indole, pyrimidine and cytidine, pyrroles such as biliverdin and bilirubin, thiols and thiolates such as  $\text{EtSH}$  and  $\text{PhSH}$ ,  
15 chloride, bromide and iodide, carboxylates such as formate, acetate, and oxalate, ethers such as  $\text{Et}_2\text{O}$  and tetrahydrofuran, alcohols such as  $\text{EtOH}$ , and nitriles such as  $\text{MeCN}$ . Particularly preferred are coordinating ligands, such as amino acids, which render the carbonyl  
20 complex stable in aqueous solution. Other possible ligands are conjugated carbon groups, such as dienes. One class of ligands which can provide metal carbonyl compounds of use in this invention is cyclopentadienyl ( $\text{C}_5\text{H}_5$ ) and substituted cyclopentadienyl. The substituent  
25 group in substituted cyclopentadienyl may be for example an alkanol, an ether or an ester, e.g.  $-(\text{CH}_2)_n\text{OH}$  where n is 1 to 4, particularly  $-\text{CH}_2\text{OH}$ ,  $-(\text{CH}_2)_n\text{OR}$  where n is 1 to 4 and R is hydrocarbon preferably alkyl of 1 to 4 carbon atoms and  $-(\text{CH}_2)_n\text{OOCR}$  where n is 1 to 4 and R is  
30 hydrocarbon preferably alkyl of 1 to 4 carbon atoms. The preferred metal in such a cyclopentadienyl or substituted cyclopentadienyl carbonyl complex is Fe. Preferably the

cyclopentadienyl carbonyl complex is cationic, being associated with an anion such as chloride.

Thus the properties of pharmaceutical compositions of the present invention may be tailored as required by appropriate choice of metal centres and number and type of associated ligands in the metal carbonyl compound.

The metal carbonyl compound may further comprise a targeting moiety, to facilitate release of CO at an appropriate site. The targeting moiety is typically capable of binding a receptor on a particular target cell surface, in order to promote release of CO at the required site. The targeting moiety may be a part of a modulating ligand capable of binding to a receptor found on the surface of the target cells, or may be derived from another molecule, such as an antibody directed against a particular receptor, joined to the complex by a suitable linker.

The present invention also includes as the metal carbonyl component a compound of the formula  $M(CO)_x A_y$  where x is at least one, y is at least one, M is a metal, A is an atom or group bonded to M by an ionic, covalent or coordination bond but is not CO, and, in the case where  $y > 1$ , each A may be the same or different, or a pharmaceutically acceptable salt of such a compound. Typically, M is a transition metal, particularly of groups 6 to 10, and A may be selected from neutral or anionic ligands, such as halide, or derived from Lewis bases and having N, P, O, S or C as the coordinating atom(s). Mono-, bi- or polydentate ligands may be used. More details of preferred metals and ligands are given above. The molecular weight of this compound is preferably less than 1000, e.g. not more than 822. Some

CO-releasing carbonyls and their release properties are given in Figs. 3A-3F.

The carbonyl complex should be pharmaceutically acceptable, in particular non-toxic or of acceptable toxicity at the dosage levels envisaged.

The metal carbonyl component may be a compound of the formula

$M(CO)_x A_y B_z$  where

M is Fe, Co or Ru,

x is at least one,

y is at least one,

z is zero or at least one,

each A is a ligand other than CO and is monodentate or polydentate with respect to M and is selected from the amino acids

alanine

arginine

asparagine

aspartic acid

cysteine

glutamic acid

glutamine

glycine

histidine

isoleucine

leucine

lysine

methionine

phenylalanine

proline

serine

threonine

tryptophan

tyrosine

valine

$[O(CH_2COO)_2]^{2-}$  and

$[NH(CH_2COO)_2]^{2-}$ , and

5 B is optional and is a ligand other than CO.

x is preferably 3, y is preferably 1 and z is preferably 1.

The term amino acid here used includes the species obtained by loss of the acidic hydrogen, such as  
10 glycinate.

B<sub>z</sub> represents one or more optional other ligands. There are no particular limitations on B, and ligands such as halides, e.g. chloride, bromide, iodide, and carboxylates, e.g. acetate may be used.

15 M is selected from Fe, Ru and Co. These metals are preferably in low oxidation states, as described above.

Use of the known iron compounds  $[Fe(SPh)_2(2,2'$ -bipyridine) $(CO)_2]$  and  $[Fe(SPh)_2(NH_2CH_2CH_2NH_2)(CO)_2]$  is also envisaged in this invention.

20 The guanylate cyclase stabilizer/stimulant compound may be any compound which stimulates production of guanylate cyclase or which stabilizes guanylate cyclase, in particular the active form of guanylate cyclase. A single compound can be used or a combination of compounds  
25 can be used either for simultaneous or sequential administration, i.e. the various aspects include/use at least one guanylate cyclase stimulant/stabilizer.

Examples include 3-(5'-hydroxymethyl-2'-furyl)-1-benzyl-indazole (YC-1), 4 pyrimidinamine-5-cyclopropyl-2-  
30 [1-[(2-fluorophenyl)methyl]-1H-pyrazolo[3,4-b]pyridin-3-yl] (BAY 41-2272), BAY 50-6038 (ortho-PAL), BAY 51-9491 (meta PAL), and BAY 50-8364 (para PAL). The structures of ortho-, meta- and para- PAL are shown in Figure 2.

These compounds have been found to bind to an activation site on the guanylate cyclase (9) and any other compounds that similarly bind to the site may be useful as the guanylate cyclase stabilizer/ stimulant. Also useful are NO donors and 1-benzyl-3-(3<sup>1</sup>-ethoxycarbonyl)phenyl-indazole, 1-benzyl-3-(3<sup>1</sup>-hydroxymethyl)phenyl-indazole, 1-benzyl-3-(5<sup>1</sup>-diethylaminomethyl)-furyl-indazole, 1-benzyl-3-(5<sup>1</sup>-methoxymethyl)furyl-indazole, 1-benzyl-3-(5<sup>1</sup>-hydroxymethyl)furyl-6-methyl-indazole, 1-benzyl-3-(5<sup>1</sup>-hydroxymethyl)-furyl-indazole, 1-benzyl-3-(5<sup>1</sup>-hydroxymethyl)-furyl-6-fluoro-indazole, 1-benzyl-3-(5<sup>1</sup>-hydroxymethyl)-furyl-6-methoxy-indazole, and 1-benzyl-3-(5<sup>1</sup>-hydroxymethyl)-furyl-5,6-methylenedioxindazole or pharmaceutically acceptable salts thereof.

The metal carbonyl component and/or guanylate cyclase stabilizer/stimulant component typically comprise a pharmaceutically acceptable excipient, carrier, buffer, stabiliser or other materials well known to those skilled in the art. Such materials should be non-toxic and should not interfere unduly with the efficacy of the active ingredient. The precise nature of the carrier or other material may depend on the route of administration, e.g. oral, intravenous, subcutaneous, nasal, intramuscular, intraperitoneal, or suppository routes.

Components/preparations for oral administration may be in tablet, capsule, powder or liquid form. A tablet may include a solid carrier such as gelatin or an adjuvant or a slow-release polymer. Liquid compositions/preparations generally include a liquid carrier such as water, petroleum, animal or vegetable oils, mineral oil or synthetic oil. Physiological saline solution, dextrose or other saccharide solution or

glycols such as ethylene glycol, propylene glycol or polyethylene glycol may be included. Pharmaceutically acceptable amounts of other solvents may also be included, in particular where they are required for dissolving the particular metal carbonyl compound contained in the composition. The composition may further comprise pharmaceutically acceptable additives such as suspending agents (e.g. sorbitol syrup, cellulose derivatives or hydrogenated edible fats); emulsifying agents (e.g. lecithin or acacia); non-aqueous vehicles (e.g. almond oil, oily esters, ethyl alcohol or fractionated vegetable oils); preservatives (e.g. methyl or propyl-p-hydroxybenzoates or sorbic acid); and energy sources (e.g. carbohydrates such as glucose, fats such as palmitate or amino acid).

For intravenous, cutaneous or subcutaneous injection, or injection at the site of affliction, the active ingredient will typically be in the form of a parenterally acceptable solution which is pyrogen-free and has suitable pH, isotonicity and stability. Those of relevant skill in the art are well able to prepare suitable solutions using, for example, isotonic vehicles such as Sodium Chloride Injection, Ringer's Injection, Lactated Ringer's Injection. Preservatives, stabilisers, buffers, antioxidants and/or other additives may be included, as required. Delivery systems for needle-free injection are also known, and compositions for use with such systems may be prepared accordingly.

Administration is preferably in a prophylactically effective amount or a therapeutically effective amount (as the case may be, although prophylaxis may be considered therapy), this being sufficient to show benefit to the individual. The actual amount

administered, and rate and time-course of administration, will depend on the nature and severity of what is being treated. Prescription of treatment, e.g. decisions on dosage etc, is within the responsibility of general practitioners and other medical doctors, and typically takes account of the disorder to be treated, the condition of the individual patient, the site of delivery, the method of administration and other factors known to practitioners. Examples of the techniques and protocols mentioned above can be found in Remington's Pharmaceutical Sciences, 16th edition, Osol, A. (ed), 1980.

When formulating compositions/preparations according to the present invention, the toxicity of the active ingredient, stimulant/stabilizer and/or the solvent must be considered. The balance between medical benefit and toxicity should be taken into account. The dosages and formulations will typically be determined so that the medical benefit provided outweighs any risks due to the toxicity of the constituents. Examples include St Thomas Hospital solutions, Euro-Collins solutions, University of Wisconsin solutions, Celsior solutions, Ringer Lactate solutions, Bretschneider solutions and perfluorocarbons.

The metal carbonyl compound and the stimulant/stabilizer can be formulated into a single composition that can be in any physical form. In this case, the components will be administered simultaneously. Alternatively, the components can be formulated into two compositions which can be administered simultaneously or sequentially.

Throughout this application, references to medical treatment are intended to include both human and veterinary treatment, and references to pharmaceutical



compositions are accordingly intended to encompass compositions for use in human or veterinary treatment.

#### INTRODUCTION OF THE DRAWINGS

5 Experimental data illustrating the present invention will now be described by reference to the accompanying figures, in which:

Fig. 1A shows vasodilatory effects of CORM-3 alone and in combination with YC-1 obtained in Example 1;

10 Fig. 1B shows percentage relaxation obtained in Example 1;

Fig. 2 shows structures of ortho-, meta- and para-PAL; and

15 Figs. 3A to F show carbon monoxide releasing molecules;

Figs. 4A and 4B show absorbance data obtained in Example 2;

Fig. 5 shows relaxation data of Example 3;

Figs. 6A and 6B show data of Example 4A;

20 Figs. 7A, 7B, 7C and 7D show data of Example 4B;

Figs. 8A and 8B show data of Example 4C; and

Fig. 9 shows data of Example 5.

#### EMBODIMENTS OF THE INVENTION AND EXAMPLES

25 Stock solutions of CORM-3 (100 mM) were prepared by solubilizing the compound in distilled water prior to the experiment. Tricarbonyldichloro ruthenium(II) dimer ( $[\text{Ru}(\text{CO})_3\text{Cl}_2]_2$ ), 3-(5'-hydroxymethyl-2'-furyl)-1-benzyl-indazole (YC-1) and all other reagents were purchased  
30 from Sigma-Aldrich (Poole, Dorset).

All data are expressed as mean  $\pm$  s.e.m. Differences between the groups analysed were assessed by the Student's two-tailed t-test, and an analysis of variance

(ANOVA) was performed where more than two treatments were compared. Results were considered statistically significant at  $P < 0.05$ .

5 In the Examples below, "mM" and "μM" signify concentrations (millimolar and micromolar respectively).

### Syntheses

Synthetic methods for obtaining the metal carbonyl compounds of Figs. 3A to 3F were described in  
10 WO02/092075, the entire content of which is incorporated herein by reference. These compounds are examples of those useful in the present invention. The CO release data in Figs. 3A to 3F is explained in WO02/092075.

#### 15 Preparation of $\text{Ru}(\text{CO})_3\text{Cl}(\text{NH}_2\text{CH}_2\text{CO}_2)$ [ $M_R$ 294.5]

Glycine complex. Reference number: CORM-3

[ $\text{Ru}(\text{CO})_3\text{Cl}_2$ ]<sub>2</sub> (0.129g, 0.25 mmol) and glycine (0.039g, 0.50 mmol) were placed under nitrogen in a round  
20 bottomed flask. Methanol (75 cm<sup>3</sup>) and sodium ethoxide (0.034g, 0.50 mmol) were added and the reaction stirred for 18 hours. The solvent was then removed under pressure and the yellow residue redissolved in THF, filtered and excess 40-60 light petroleum added. The  
25 yellow solution was evaporated down to give a pale yellow solid (0.142g, 96%). CORM-3 was stored in closed vials at 4 °C and used freshly on the day of the experiments.

#### Alternative, preferred preparation of

#### $\text{Ru}(\text{CO})_3\text{Cl}(\text{NH}_2\text{CO}_2\text{CO}_2)$ [ $M_R$ 294.6]

30 Glycine complex. Reference number: CORM-3

[ $\text{Ru}(\text{CO})_3\text{Cl}_2$ ]<sub>2</sub> (0.129g, 0.25 mmol) and glycine (0.039g, 0.50 mmol) were placed under nitrogen in a round bottomed flask. Methanol (40 cm<sup>3</sup>) and sodium methoxide

(0.5M solution in MeOH, 1.00 cm<sup>3</sup>, 0.50 mmol) were added and the reaction stirred for 18 hours. HCl (2.0M solution in diethyl ether) was added in small aliquots until the IR band at 1987 cm<sup>-1</sup> in solution IR spectroscopy could no longer be detected. The solvent was then removed under reduced pressure and the yellow residue redissolved in THF, filtered and an excess of 40-60 light petroleum added. The resulting precipitate was isolated by pipetting off the mother liquor and drying under high vacuum. The same work up was repeated for the mother liquor once concentrated. The colour of the product varied between white and pale yellow and was produced in an average yield of 0.133g, (90%).

#### 15 Example 1

##### Preparation of isolated rat aortic rings and experimental protocol

The method for the preparation of isolated aortic rings has been previously described (5; 7). The thoracic aorta was isolated from Sprague-Dawley rats (350-450 g) and flushed with cold Krebs-Henseleit buffer (4°C, pH 7.4) containing (in mM): 118 NaCl, 4.7 KCl, 1.2 KH<sub>2</sub>PO<sub>4</sub>, 1.2 MgSO<sub>4</sub>·7H<sub>2</sub>O, 22 NaHCO<sub>3</sub>, 11 Glucose, 0.03 K<sup>+</sup>EDTA, 2.5 CaCl<sub>2</sub> and supplemented with 10 µM indomethacin. Each aorta was trimmed of adventitial tissue and ring sections (~3 mm length) were produced from the mid aortic segment. The rings were then mounted between two stainless steel hooks in 9-ml organ baths containing Krebs-Henseleit buffer which was maintained at 37 °C and continuously gassed with 95% O<sub>2</sub>-5% CO<sub>2</sub>. One hook was attached to a Grass FT03 isometric force transducer whilst the other was anchored to a sledge for regulation of the resting

tension of the aortic ring. The rings were initially equilibrated for 30 min under a resting tension of 2g which was previously determined to be optimal. Continuous recording of tension was made on a Grass 7D polygraph (Grass Instruments, Quincy, MA) in combination with a Biopac MP100 system using AcqKnowledge<sup>TM</sup> software (Linton Instruments, Norfolk, UK). Before each protocol was carried out, rings were contracted with a standard dose of KCl (100 mM) in order to provide an internal reference and to control for variability in contractile responsiveness between tissues. The relaxation response to CORM-3 (25  $\mu$ M) in the presence or absence of YC-1 (5  $\mu$ M final concentration, 30 min pre-incubation) was assessed in aortic rings pre-contracted with phenylephrine (1  $\mu$ mol/L).

### Results

Figure 1A shows the typical plots of the vascular reactivity to phenylephrine and the vasodilatory effects of CORM-3 alone or in combination with YC-1 in this Example. In the absence of YC-1, three sequential additions of CORM-3 (25  $\mu$ M each) to the pre-contracted ring elicited vasorelaxation (see top plot). If the relaxation is expressed as a percentage of the maximal phenylephrine-mediated contraction, then we can calculate that CORM-3 produced a 10.3% relaxation after the first addition, 24.1% relaxation after the second addition and 38% after the third addition (Figure 1B). The presence of YC-1 in the organ bath amplified the observed vasodilatory effect mediated by CORM-3 (see bottom plot, Figure 1A) and produced a 33% relaxation after the first addition of the CO carrier, 66.6% relaxation after the second addition and 80.9% after the third addition

(Figure 1B). These data indicate that CO released by CORM-3 mediates a vasodilatory effect which can be further enhanced by addition of the sGC activator YC-1. In view of the fact that increased cGMP levels by YC-1 in the presence of CO led to complete inhibition of platelet aggregation (1), the results presented here point to the potential therapeutic use of CORM-3 in combination with YC-1 in those pathophysiological conditions characterized by increased platelet aggregation.

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Example 2 and Example 3 are presented here as background, to illustrate the effects of CORM-3 in CO release and vasorelaxation.

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#### Example 2

##### Conversion of myoglobin (Mb) to carbon monoxide myoglobin (MbCO) by CO gas and CORM-3.

Myoglobin (Mb) in its reduced state displays a characteristic spectrum with a maximal absorption peak at 555 nm (see Fig. 4A, dotted line). When a solution of Mb (50  $\mu$ M) is bubbled for 1 min with CO gas (1%), a rapid conversion to carbon monoxide myoglobin (MbCO) is observed. As shown in Fig. 4A (solid line), MbCO displays a characteristic spectrum with two maximal absorption peaks at 540 and 576 nm, respectively. This method has been previously developed to monitor and determine the amount of CO released from CO-RMs (7). Indeed, when CORM-3 ( $[\text{Ru}(\text{CO})_3\text{Cl}(\text{glycinato})]$ ) is first solubilized in water and then added to the Mb solution, formation of MbCO is observed (Fig. 4B, solid line). The amount of MbCO formed is instantaneous and indicates that 1 mole of CO per mole of CORM-3 is promptly released (7). Interestingly, CO is rapidly lost when CORM-3 is left incubating overnight at

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37 °C in phosphate buffer at pH=7.4. This step allows the generation of an inactive compound (iCORM-3) that does not convert Mb to MbCO (see Fig. 4B, dotted line) and is used as negative control of CORM-3 when testing for its pharmacological activities.

### Example 3

#### Comparison between CORM-3 and iCORM-3 in their ability to elicit vasorelaxation.

CORM-3 (100  $\mu$ M) added to isolated aortic rings pre-contracted with phenylephrine (Phe) promoted approximately 54% relaxation within few minutes from addition (See Fig. 5, solid line). In contrast, 100  $\mu$ M iCORM-3 (which is incapable of releasing CO) did not cause any significant change in vessel tone (see Fig. 5, dotted line). These results indicate that CO liberated from CORM-3 is directly responsible for the observed pharmacological effect.

### Examples 4A, 4B and 4C

#### Preparation of isolated rat aortic rings and experimental protocol

The preparation of isolated aortic rings and recording of tension was as in Example 1. Before each protocol was carried out, rings were contracted with a standard dose of KCl (100 mM) in order to provide an internal reference and to control for variability in contractile responsiveness between tissues. The relaxation response to CORM-3 (25, 50 and 100  $\mu$ M) in the presence and absence of YC-1 (1  $\mu$ M final concentration, 30 min pre-incubation) was assessed in aortic rings pre-contracted with phenylephrine (1  $\mu$ M). CORM-3 was added to the aortic rings as three cumulative additions at 10

minute intervals and the percentage of relaxation produced was recorded after each addition. In another set of experiments, an inhibitor of guanylate cyclase (H-(1,2,4) oxadiazolo (4,3-a) quinoxallin-1-one, here called ODQ, 10  $\mu$ M) and an inhibitor of ATP-dependent potassium channels (glibenclamide, 10  $\mu$ M) were tested for their ability to modulate CORM-3-dependent vasorelaxation. ODQ and glibenclamide were added to the aortic ring preparation prior to CORM-3 addition (15 min and 30 min, respectively). To test the possibility that the nitric oxide (NO) synthase pathway is involved in the vasorelaxing effects mediated by CORM-3, a NO synthase inhibitor (L-nitroarginine methyl ester or L-NAME, 10  $\mu$ M) was added to the aortic rings 30 min prior to CORM-3 addition. An additional set of experiments was performed in which the vascular endothelium was removed from the aortic tissue prior to CORM-3 addition. As an index of direct guanylate cyclase activation by CORM-3, the levels of cyclic guanosine monophosphate (cGMP) were also measured in freeze-clamped aortic tissue extracts using a commercial ELISA kit (Amersham) as previously described (7). The levels of cGMP in aortic tissue was measured 8 min after each of the three cumulative additions of CORM-3 (100  $\mu$ M) and compared to the basal levels of cGMP (control, no treatment).

#### Results - Example 4A

##### Effects of guanylate cyclase and potassium channel inhibitors on the vasorelaxation mediated by CORM-3.

In Figs. 6, 7 and 8, in the graphs reporting construction, the 100% value at "Addition 0" is the value of vasocontractility before addition of CORM-3.

Pre-contracted aortic rings were treated with increasing concentrations of CORM-3 (25, 50 and 100  $\mu$ M) as described above. Three cumulative additions of CORM-3 were given and the percentage of vasorelaxation was calculated at the end of each addition. As shown in Fig. 6A, CORM-3 caused a significant relaxation in a concentration-dependent manner (reported in the graph as a decrease in contraction). It can be seen from the graph that after treatment with 100  $\mu$ M CORM-3, the percentage of relaxation elicited by the three cumulative additions were  $37.5 \pm 5.3\%$ ,  $48.2 \pm 4.4\%$  and  $53.9 \pm 4.3\%$ , respectively. Addition of iCORM-3 (100  $\mu$ M), which does not release CO, did not produce any detectable change in vessel contractility. The data are represented as the mean  $\pm$  S.E.M. of 6 independent experiments for each group (\* $p < 0.05$  vs. iCORM-3). Fig. 6B shows the effect of ODQ (a guanylate cyclase inhibitor) and glibenclamide (Gli, an inhibitor of ATP-dependent potassium channels) on CORM-3-mediated vasorelaxation. Both inhibitors were very effective in attenuating the relaxation caused by CORM-3. For instance, the  $37.5 \pm 5.3\%$  relaxation elicited by CORM-3 following the first addition was reduced to  $1.0 \pm 0.8\%$  and  $13.2 \pm 4.1\%$  in the presence of ODQ and glibenclamide, respectively. During the first two additions of CORM-3, the inhibition of relaxation was more pronounced with ODQ. The data are represented as the mean  $\pm$  S.E.M. of 6 independent experiments for each group (\* $p < 0.05$  vs. CORM-3).

#### 30 Results - Example 4B

##### Effect of YC-1 on CORM-3-mediated vasorelaxation.

YC-1 sensitizes guanylate cyclase (sGC) to the effect of CO gas as previously reported by Friebe and



colleagues (1; 2). To test whether a similar effect could be observed in the presence of CORM-3, YC-1 was added to the aortic ring preparation 30 min prior to the addition of CORM-3. As shown in Fig. 7A, the presence of YC-1  
5 potentiated the relaxation elicited by CORM-3 (note: pre-treatment of YC-1 alone did not cause any significant change in vessel contractility). Specifically, YC-1 significantly amplified the reduction in contractility mediated by CORM-3 at all concentrations used. For  
10 instance, after the third addition, 25  $\mu$ M CORM-3 alone caused approximately 31% relaxation whereas pre-treatment of vessels with YC-1 increased the extent of relaxation to 77% (Fig. 7B). A similar pattern showing a  
15 potentiation of relaxation by YC-1 was obtained in experiments using 50  $\mu$ M (Fig. 7C) and 100  $\mu$ M (Fig. 7D) CORM-3. These results indicate that CO released by CORM-3 mediates a vasodilatory effect which can be further  
enhanced by addition of the sGC activator YC-1. The data are represented as the mean $\pm$ S.E.M. of 6 independent  
20 experiments for each group (\* $p$ <0.05 vs. CORM-3).

#### Results - Example 4C

##### Effects of L-NAME and removal of the endothelium on CORM-3-mediated vasorelaxation.

25 The NO synthase inhibitor, L-NAME, was used to ascertain whether CORM-3 mediates its effects through a mechanism involving the endogenous generation of NO. As shown in Fig. 8A, L-NAME (100  $\mu$ M) significantly  
30 attenuated the relaxation effect elicited by each addition of CORM-3. For instance, following the first addition, CORM-3 caused approximately 37% relaxation but the presence of L-NAME in the organ bath reduced the extent of relaxation to 5%. Interestingly, the effect of

L-NAME was reversed by increasing the concentration of CORM-3 (200 and 400  $\mu$ M). A similar effect was obtained by removing the endothelium from the vessel. As shown in Fig. 8B, aortic rings without the endothelium (indicated in the graph by -E) did not respond to CORM-3 in the same way as intact vessels (+E) unless the concentration of CORM-3 was increased to 400  $\mu$ M. These results indicate that NO and other factors produced by the endothelium facilitates vasorelaxing capacity of CORM-3 to promote vasorelaxation. The data are represented as the mean  $\pm$  S.E.M. of 6 independent experiments for each group (\* $p$  < 0.05 vs. CORM-3).

#### Example 5

##### Effect of CORM-3 and YC-1 on mean arterial pressure.

Lewis rats (280-350 g) were anaesthetised by intramuscular injection of 1 ml/kg Hypnorm. Specially designed femoral artery and venous catheters were then surgically implanted as previously described (5; 6) and blood pressure monitored continuously using a polygraph recorder. Rats were administered with one bolus of CORM-3 (30  $\mu$ moles/kg) and after 20 min with a second bolus. CORM-3 was injected intravenously and the change in mean arterial pressure MAP recorded 20 min after each injection. In the experiments using YC-1, the sGC activator (1.2  $\mu$ moles/kg) was administered intravenously 5 min prior to the first injection of CORM-3. The effect of CORM-3 alone or in combination with YC-1 on mean arterial pressure (MAP) in vivo is summarized in Fig. 7. Two bolus of CORM-3 (30  $\mu$ moles/kg) were injected intravenously 20 min apart from each other and the change in MAP recorded. In the experiments using YC-1, the sGC activator (1.2  $\mu$ moles/kg) was administered intravenously

5 min prior to the first injection of CORM-3. As shown, CORM-3 alone produced a rapid and significant decrease in MAP; specifically, the first injection of CORM-3 produced a decrease in MAP of  $9.4 \pm 2.8$  mmHg whereas the second  
5 bolus of CORM-3 resulted in a drop of  $13.3 \pm 4.9$  mmHg. The injection of YC-1 potentiated the hypotensive effects mediated by CORM-3. Administration of YC-1 lead to a decrease in MAP ( $7.0 \pm 1.6$  mmHg) after 5 min; the subsequent injections of CORM-3 amplified this effect  
10 resulting in a decrease in MAP of  $37.0 \pm 2.4$  and  $22.0 \pm 2.3$  mmHg after the first and second injection, respectively. These results indicate that CO released by CORM-3 mediates an hypotensive effect *in vivo* which can be further enhanced in combination with the sGC activator  
15 YC-1.

While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this  
20 disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

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CLAIMS:

1. A pharmaceutical preparation, comprising a metal carbonyl compound or pharmaceutically acceptable salt thereof, a guanylate cyclase stimulant or stabilizer and at least one pharmaceutically acceptable carrier.
2. A pharmaceutical preparation according to claim 1, wherein the metal carbonyl makes available CO suitable for physiological effect, for delivery of carbon monoxide to a physiological target.
3. A pharmaceutical preparation according to claim 2, wherein said metal carbonyl compound makes CO available by at least one of the following means:
  - 1) CO derived by dissociation of the metal carbonyl is present in the composition in dissolved form;
  - 2) on contact with a solvent or ligand the metal carbonyl releases CO;
  - 3) on contact with a tissue, organ or cell the metal carbonyl releases CO;
  - 4) on irradiation the metal carbonyl releases CO.
4. A pharmaceutical preparation according to claim 1, 2 or 3, wherein said metal carbonyl compound and said guanylate cyclase stimulant/stabilizer are combined in a single composition.
5. A pharmaceutical preparation according to claim 1, 2 or 3, wherein said metal carbonyl compound and said guanylate cyclase stabilizer/stimulant are in separate compositions for administration simultaneously or sequentially.

6. A pharmaceutical preparation according to any one of the preceding claims wherein the metal carbonyl compound has the formula  $M(CO)_x A_y$ , where x is at least one, y is at least one, M is a metal, the or each A is an atom or group bonded to M by an ionic, covalent or coordination bond but is not CO, and in the case where  $y > 1$  each A may be the same or different, or a pharmaceutically acceptable salt of such a compound.

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7. A pharmaceutical preparation according to claim 6, wherein M is a transition metal.

8. A pharmaceutical preparation according to claim 6 or claim 7, wherein A is selected from neutral or anionic ligands, such as halide, or derived from Lewis bases and having N, P, O, S or C as the coordinating atom(s).

9. A pharmaceutical preparation according to any one of claims 1 to 5, wherein the metal carbonyl compound has the formula

$M(CO)_x A_y B_z$  where  
M is Fe, Co or Ru,  
x is at least one,  
y is at least one,  
z is zero or at least one,  
each A is a ligand other than CO and is monodentate or polydentate with respect to M and is selected from the amino acids

30

alanine  
arginine  
asparagine  
aspartic acid

31

5 cysteine  
glutamic acid  
glutamine  
glycine  
histidine  
isoleucine  
leucine  
lysine  
methionine  
10 phenylalanine  
proline  
serine  
threonine  
tryptophan  
15 tyrosine  
valine

$[O(CH_2COO)_2]^{2-}$  and

$[NH(CH_2COO)_2]^{2-}$ , and

B is optional and is a ligand other than CO.

20

10. A pharmaceutical preparation according to any one of the preceding claims wherein the guanylate cyclase stimulant/stabilizer is YC-1.

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11. A pharmaceutical composition according to any one of the preceding claims adapted for delivery by an oral, intravenous, subcutaneous, nasal, inhalatory, intramuscular, intraperitoneal or suppository route.

30

12. A method of introducing a therapeutic agent to a mammal comprising the step of administering a pharmaceutical preparation according to any one of the preceding claims.



13. A method of introducing a therapeutic agent to a mammal comprising:

- a) administering a metal carbonyl; and
- 5        b) administering a guanylate cyclase stimulant or stabiliser.

14. A method according to claim 13, wherein the metal carbonyl makes CO available for physiological effect, for  
10        delivery of CO to a physiological target.

15. A method according to claim 14, wherein said metal carbonyl compound makes CO available by at least one of the following means:

- 15        1) CO derived by dissociation of the metal carbonyl is present in the composition in dissolved form;
- 2) on contact with a solvent or ligand the metal carbonyl releases CO;
- 3) on contact with a tissue, organ or cell the  
20        metal carbonyl releases CO;
- 4) on irradiation the metal carbonyl releases CO.

16. A method according to any one of claims 13 to 15, wherein the steps of administering the metal carbonyl and  
25        guanylate cyclase stimulant/stabilizer are simultaneous.

17. A method according to any one of claims 13 to 15, wherein the steps of administering the metal carbonyl and guanylate cyclase stimulant/stabilizer are sequential.  
30

18. A method according to any one of claims 13 to 17, wherein the metal carbonyl compound has the formula  $M(CO)_x A_y$  where x is at least one, y is at least one, M is

a metal, the or each A is an atom or group bonded to M by an ionic, covalent or coordination bond but is not CO, and in the case where  $y > 1$  each A may be the same or different, or a pharmaceutically acceptable salt of such a compound.

19. A method according to claim 18 wherein M is a transition metal.

20. A method according to claim 18 or claim 19, wherein A is selected from neutral or anionic ligands, such as halide, or derived from Lewis bases and having N, P, O, S or C as the coordinating atom(s).

21. A method according to any one of claims 13 to 17 wherein the metal carbonyl compound has the formula

$M(CO)_x A_y B_z$  where

M is Fe, Co or Ru,

x is at least one,

y is at least one,

z is zero or at least one,

each A is a ligand other than CO and is monodentate or polydentate with respect to M and is selected from the amino acids

alanine

arginine

asparagine

aspartic acid

cysteine

glutamic acid

glutamine

glycine

histidine

isoleucine  
leucine  
lysine  
methionine  
5 phenylalanine  
proline  
serine  
threonine  
tryptophan  
10 tyrosine  
valine

$[\text{O}(\text{CH}_2\text{COO})_2]^{2-}$  and

$[\text{NH}(\text{CH}_2\text{COO})_2]^{2-}$ , and

B is optional and is a ligand other than CO.

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22. A method according to any one of claims 13 to 21,  
wherein the guanylate cyclase stimulant/stabilizer is YC-  
1.

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23. A method according to any one of claims 15 to 22,  
wherein the metal carbonyl compound and/or the guanylate  
cyclase stabilizer/stimulant is administered by an oral,  
intravenous, subcutaneous, nasal, inhalatory,  
intramuscular, intraperitoneal or suppository route.

25

24. A method according to any one of claims 12 to 23,  
wherein the metal carbonyl and guanylate cyclase  
stimulant/stabilizer are administered to an  
extracorporeal body organ.

30

25. A method according to any one of claims 12 to 24,  
where the administration is for the stimulation of  
vasodilation, or for treatment of any of hypertension,

such as acute, pulmonary and chronic hypertension,  
radiation damage, endotoxic shock, inflammation,  
inflammatory-related diseases such as asthma and  
rheumatoid arthritis, hyperoxia-induced injury,  
5 apoptosis, cancer, transplant rejection,  
arteriosclerosis, post-ischemic organ damage, myocardial  
infarction, angina, haemorrhagic shock, sepsis, penile  
erectile dysfunction, adult respiratory distress syndrome  
and inhibition of platelet aggregation.

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26. A kit comprising a) a metal carbonyl compound; and  
b) a guanylate cyclase stimulant/stabilizer.

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27. A kit according to claim 26, wherein the metal  
carbonyl is capable of making available CO suitable for  
physiological effect.

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28. A kit according to claim 27, wherein said metal  
carbonyl compound makes CO available by at least one of  
the following means:

- 1) CO derived by dissociation of the metal carbonyl  
is present in the composition in dissolved form;
- 2) on contact with a solvent or ligand the metal  
carbonyl releases CO;
- 25 3) on contact with a tissue, organ or cell the  
metal carbonyl releases CO;
- 4) on irradiation the metal carbonyl releases CO.

30

29. A kit according to claim 26 or claim 27, wherein  
said metal carbonyl compound and said guanylate cyclase  
stabilizer/stimulant are in separate compositions for  
administration simultaneously or sequentially.

30. A kit according to any one of claims 26 to 29,  
wherein the metal carbonyl compound has the formula  
 $M(CO)_x A_y$  where  $x$  is at least one,  $y$  is at least one,  $M$  is  
a metal, the or each  $A$  is an atom or group bonded to  $M$  by  
an ionic, covalent or coordination bond but is not  $CO$ ,  
and in the case where  $y > 1$  each  $A$  may be the same or  
different, or a pharmaceutically acceptable salt of such  
a compound.

31. A kit according to claim 30, wherein  $M$  is a  
transition metal.

32. A kit according to claim 30 or claim 31, wherein  $A$   
is selected from neutral or anionic ligands, such as  
halide, or derived from Lewis bases and having  $N$ ,  $P$ ,  $O$ ,  $S$   
or  $C$  as the coordinating atom(s).

33. A kit according to any one of claims 26 to 29,  
wherein the metal carbonyl compound has the formula  
 $M(CO)_x A_y B_z$  where  
 $M$  is  $Fe$ ,  $Co$  or  $Ru$ ,  
 $x$  is at least one,  
 $y$  is at least one,  
 $z$  is zero or at least one,  
each  $A$  is a ligand other than  $CO$  and is monodentate  
or polydentate with respect to  $M$  and is selected from the  
amino acids

alanine  
arginine  
asparagine  
aspartic acid  
cysteine  
glutamic acid

glutamine  
glycine  
histidine  
isoleucine  
5 leucine  
lysine  
methionine  
phenylalanine  
proline  
10 serine  
threonine  
tryptophan  
tyrosine  
valine

15  $[\text{O}(\text{CH}_2\text{COO})_2]^{2-}$  and  
 $[\text{NH}(\text{CH}_2\text{COO})_2]^{2-}$ , and

B is optional and is a ligand other than CO.

20 34. A kit according to any one of claims 26 to 33,  
wherein the guanylate cyclase stimulant/stabilizer is YC-1.

25 35. A kit according to any one of claims 26 to 34,  
wherein the metal carbonyl and/or the guanylate cyclase  
stabilizer/stimulant is adapted for delivery by an oral,  
intravenous, subcutaneous, nasal, inhalatory,  
intramuscular, intraperitoneal or suppository route.

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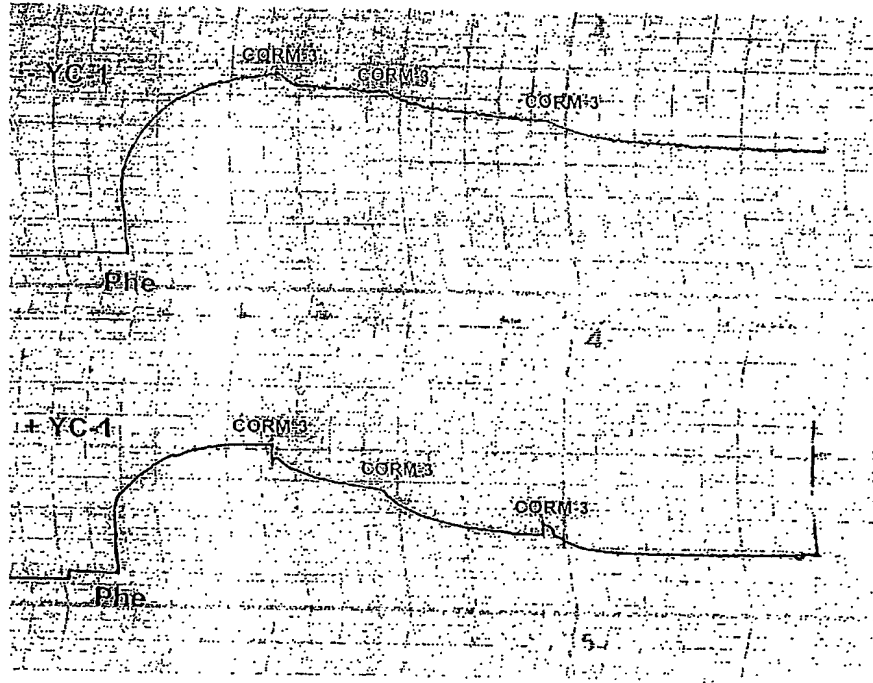


Fig. 1A

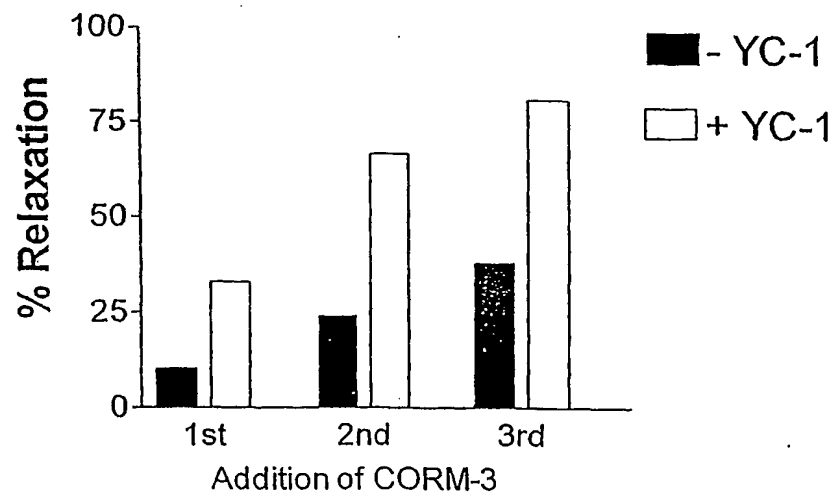
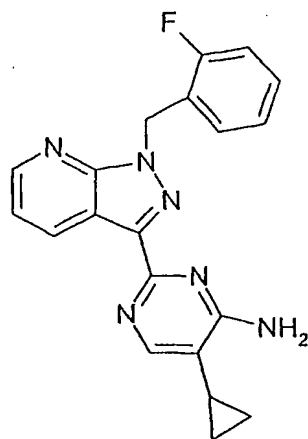


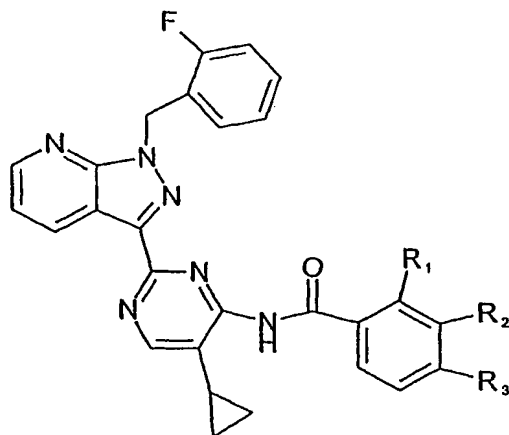
Fig. 1B

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ortho PAL : R<sub>1</sub> = N<sub>3</sub> R<sub>2</sub> = H R<sub>3</sub> = H  
meta PAL : R<sub>1</sub> = H R<sub>2</sub> = N<sub>3</sub> R<sub>3</sub> = H  
para PAL : R<sub>1</sub> = H R<sub>2</sub> = H R<sub>3</sub> = N<sub>3</sub>

Fig. 2



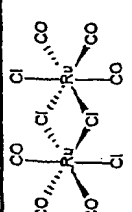
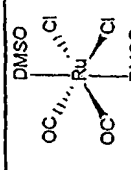
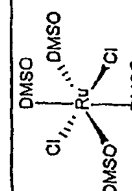
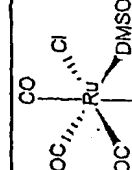
Compound	Structure	MW	CO Release (20 μmoles)					CO Release (40 μmoles)					NOTES
			0	10	20	30	30	0	10	20	30		
CO-RM-1		512	12.0 ±3.0	16.3 ±4.0	18.1 ±4.3	18.5 ±4.8	18.5 ±4.8	28.5 ±0.4	32.0 ±0.2	34.5 ±0.5	35.6 ±0.4	Soluble in DMSO	
CO-RM-1a		384	7.2 ±0.6	8.6 ±0.3	8.0 ±0.4	7.5 ±0.4	7.5 ±0.4	16.9 ±0.6	18.4 ±0.3	17.3 ±0.3	16.7 ±0.2	Soluble in DMSO	
Negative control		484	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Soluble in H <sub>2</sub> O	
CO-RM-1b		334	6.4 ±1.2	7.3 ±0.6	8.2 ±0.1	8.7 ±0.3	8.7 ±0.3	11.7 ±0.8	13.7 ±0.9	14.0 ±1.1	14.4 ±0.6	Soluble in DMSO	
CO-RM-10	$[\text{Ru}(\text{CO})_2\text{Cl}_2]_n$	(228)	2.6 ±0.6	9.8 ±0.3	12.7 ±0.1	13.8 ±0.9	13.8 ±0.9	8.6 ±0.7	21.0 ±1.1	24.4 ±1.0	26.3 ±1.2	Soluble in DMSO	

Fig. 3A

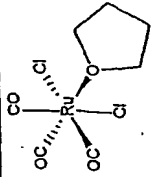
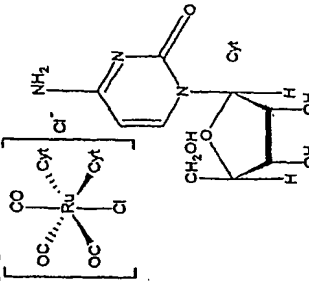
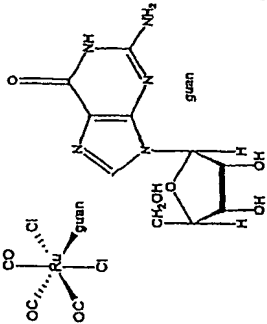
CO-RM-11 Ligand: THF		328	5.6 ±0.6	5.9 ±0.6	6.2 ±1.1	6.2 ±1.2	10.9 ±0.2	12.3 ±0.4	13.3 ±0.4	13.7 ±0.2	Soluble in DMSO
CO-RM-16 Ligand: Cytidine		742	N.D.	1.4 ±0.4	2.1 ±0.1	2.8 ±0.4	0.8 ±0.4	5.5 ±0.4	8.4 ±0.8	9.8 ±0.9	Soluble in H <sub>2</sub> O
CO-RM-17 Ligand: Guanosine		539	5.9 ±0.1	8.2 ±0.4	8.5 ±0.3	8.6 ±0.4	11.5 ±0.4	15.0 ±0.4	15.6 ±0.4	16.2 ±0.3	Soluble in H <sub>2</sub> O

Fig. 3B

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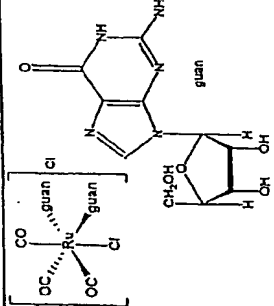
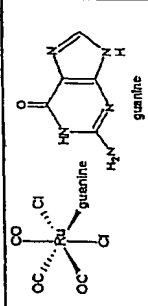
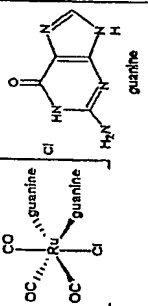
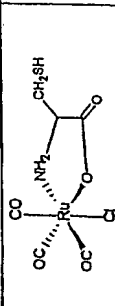
CO-RM-18 Ligand: Guanosine		822	10.1 ±0.9	14.3 ±0.4	14.1 ±0.5	13.5 ±0.4	25.4 ±1.0	29.5 ±1.5	29.5 ±1.4	28.7 ±1.3	Soluble in H <sub>2</sub> O
CO-RM-22 Ligand: Guanine		407	0.1 ±0.1	0.8 ±0.3	1.0 ±0.3	2.3 ±0.1	0.7 ±0.1	1.9 ±0.1	2.3 ±0.1	2.4 ±0.1	Soluble in H <sub>2</sub> O ppt
CO-RM-23 Ligand: Guanine		558	1.2 ±0.1	1.3 ±0.2	1.3 ±0.1	1.0 ±0.2	2.7 ±0.3	2.7 ±0.3	2.7 ±0.4	2.3 ±0.2	Soluble in H <sub>2</sub> O ppt
CO-RM-26 Ligand: Cysteine		340.5	0.6 ±0.1	1.9 ±0.1	2.3 ±0.2	2.4 ±0.2	1.9 ±0.2	3.7 ±0.1	5.1 ±0.1	5.2 ±0.1	Soluble in H <sub>2</sub> O

Fig. 3C

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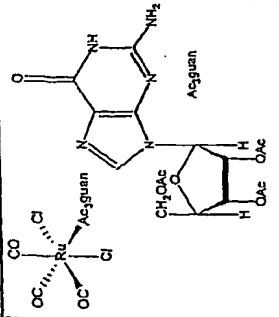
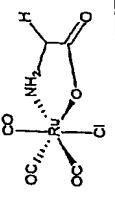
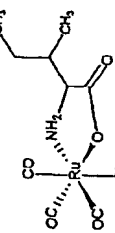
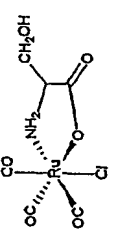
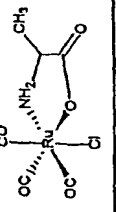
CO-RM-29 Ligand: Triacetylle- guanosine		665	1.4 ±0.7	4.5 ±0.1	5.0 ±0.1	3.2 ±0.1	8.3 ±0.6	11.7 ±0.3	12.4 ±0.1	10.6 ±0.4	Soluble in H <sub>2</sub> O
CO-RM-3 Ligand: Glycine		294.5	14.2 ±0.6	17.8 ±0.7	14.3 ±0.7	12.9 ±0.7	25.2 ±1.5	24.4 ±1.0	23.8 ±0.6	23.2 ±0.3	Soluble in H <sub>2</sub> O
CO-RM-38 Ligand: Isoleucine		350.5	3.2 ±0.2	4.4 ±0.1	4.0 ±0.2	3.0 ±1.7	7.6 ±1.3	8.3 ±1.2	7.5 ±1.1	7.3 ±1.1	Soluble in H <sub>2</sub> O
CO-RM-39 Ligand: Serine		324.5	11.0 ±0.3	12.8 ±0.9	11.4 ±1.1	10.8 ±0.7	24.2 ±1.5	24.6 ±1.4	22.0 ±1.0	21.9 ±1.2	Soluble in H <sub>2</sub> O
CO-RM-40 Ligand: Alanine		308.5	9.1 ±1.1	11.9 ±0.4	11.1 ±0.3	11.0 ±0.2	20.2 ±0.6	21.3 ±0.9	19.9 ±0.9	19.6 ±0.9	Soluble in H <sub>2</sub> O

Fig. 3D

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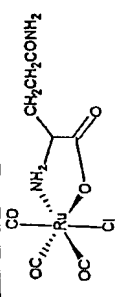
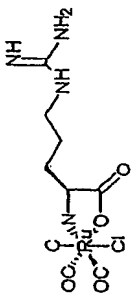
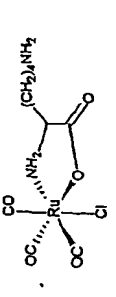
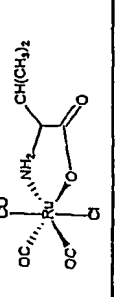
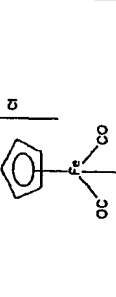
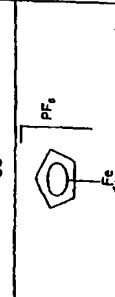
CO-RM-42 Ligand: Glutamine		365.5	8.9 ±0.4	11.1 ±0.4	12.1 ±1.4	10.1 ±0.3	21.4 ±2.1	21.8 ±2.2	20.6 ±2.0	20.0 ±1.8	Soluble in H <sub>2</sub> O
CO-RM-43 Ligand: Arginine		393.5	9.4 ±1.4	11.9 ±0.5	12.3 ±0.7	11.0 ±0.3	18.3 ±0.3	20.0 ±0.6	19.0 ±1.2	17.8 ±1.3	Soluble in H <sub>2</sub> O
CO-RM-46 Ligand: Lysine		365.5	6.0 ±0.4	7.5 ±0.8	7.2 ±1.2	6.4 ±0.8	12.6 ±0.9	13.4 ±1.2	13.2 ±1.1	11.9 ±1.0	Soluble in H <sub>2</sub> O
CO-RM-67 Ligand: L-valine		336.5	11.1 ±2.9	18.2 ±1.7	17.6 ±1.6	17.0 ±1.6	29.3 ±1.5	34.6 ±2.2	33.7 ±2.2	32.8 ±2.2	Soluble in H <sub>2</sub> O
CO-RM-70		240	0.5 ±0.2	0.9 ±0.1	2.2 ±0.2	2.7 ±0.3	0.9 ±0.1	2.0 ±0.2	4.9 ±0.2	6.3 ±0.3	Soluble in DMSO PPT
CO-RM-71		350	1.5 ±0.2	2.3 ±0.3	3.1 ±0.4	3.7 ±0.4	3.4 ±0.1	5.4 ±0.3	6.9 ±0.3	7.6 ±0.4	Soluble in DMSO PPT

Fig. 3E

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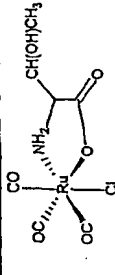
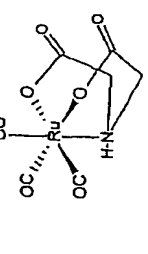
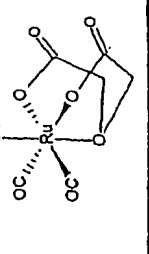
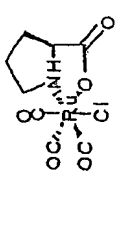
CO-RM-74 Ligand: L-Threonine		338.5	15.7 ±1.2	17.5 ±2.0	16.5 ±2.3	14.8 ±2.2	33.3 ±0.2	33.4 ±0.1	32.7 ±0.2	31.4 ±0.1	Soluble in H <sub>2</sub> O
CO-RM-97		316	2.8 ±0.6	7.0 ±0.7	7.2 ±0.9	6.6 ±0.9	7.1 ±0.5	14.3 ±0.7	14.7 ±0.8	13.6 ±0.7	Soluble in H <sub>2</sub> O
CO-RM-99		317	4.6 ±0.6	8.1 ±0.2	7.3 ±0.3	5.5 ±0.3	11.5 ±0.2	16.6 ±0.2	16.0 ±0.9	14.0 ±0.2	Soluble in H <sub>2</sub> O
CO-RM-H Ligand: L-proline		335	1.4 ±0.3	4.7 ±0.6	6.2 ±0.8	6.3 ±0.7	4.2 ±0.4	9.9 ±0.2	12.5 ±0.1	13.0 ±0.1	Soluble in H <sub>2</sub> O

Fig. 3F

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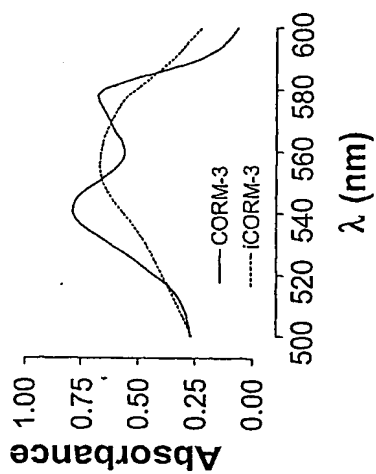


Fig. 4B

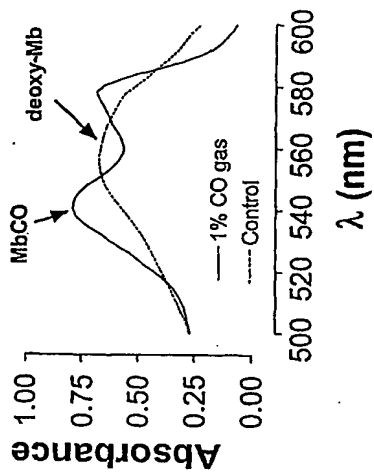


Fig. 4A

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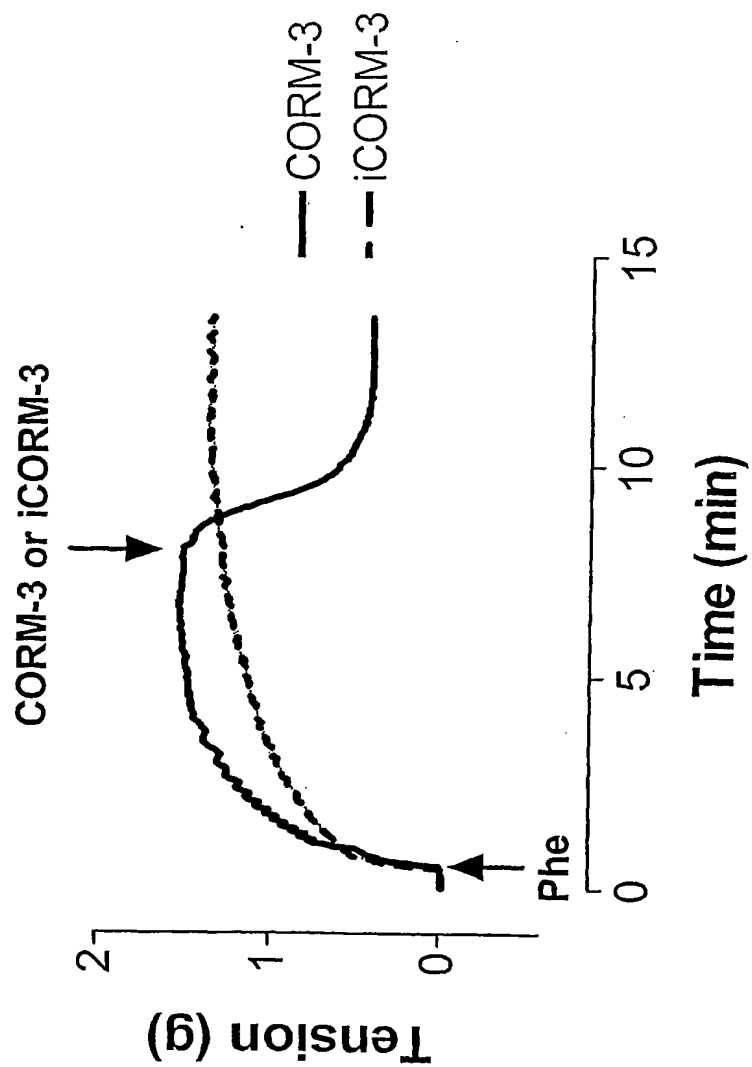


Fig. 5



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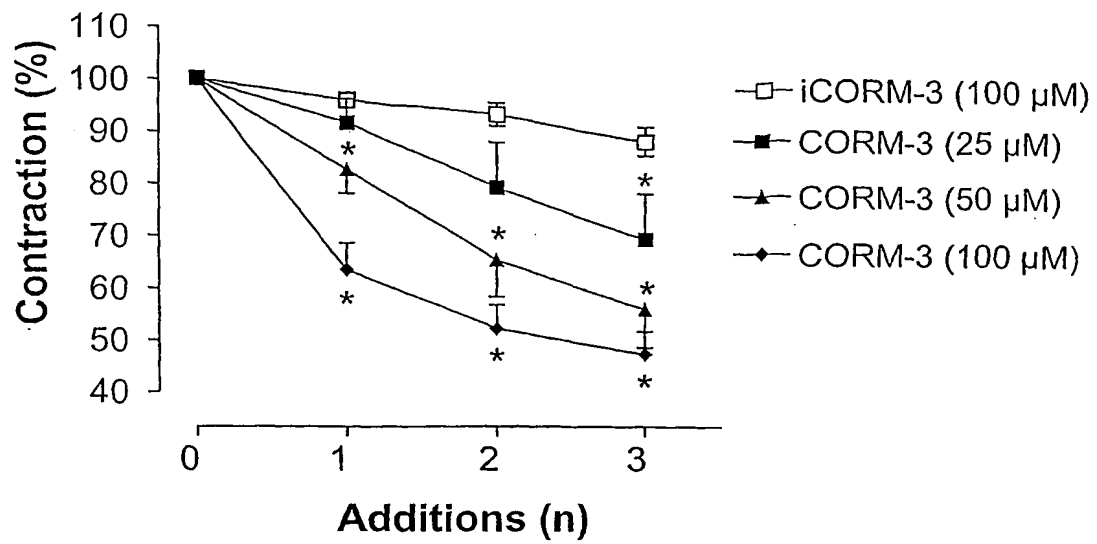


Fig. 6A

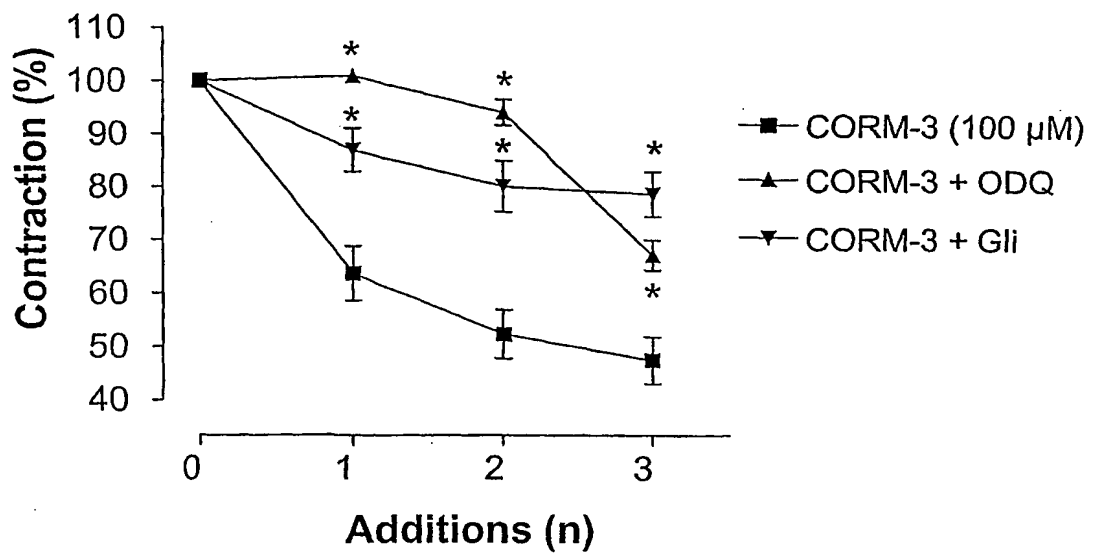


Fig. 6B

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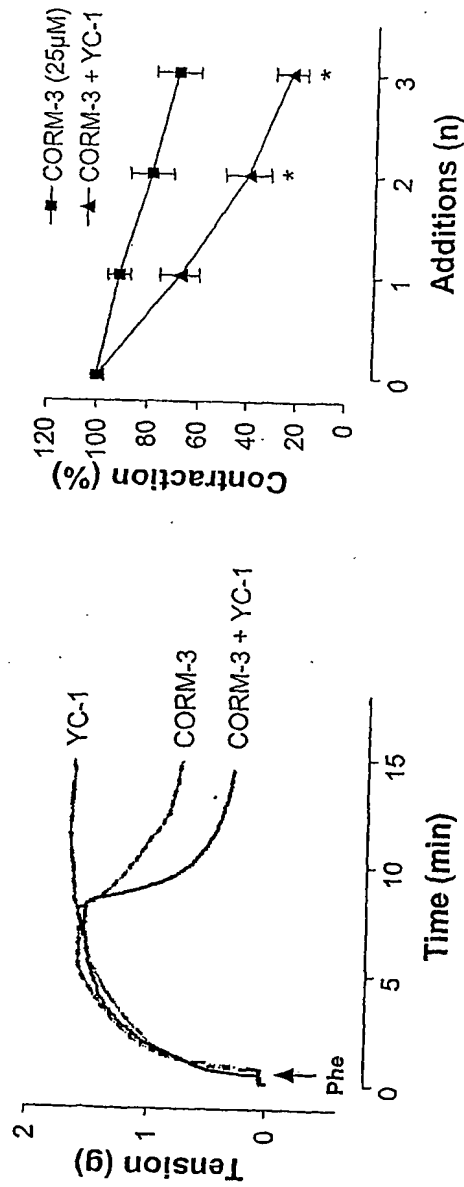


Fig. 7A

Fig. 7B

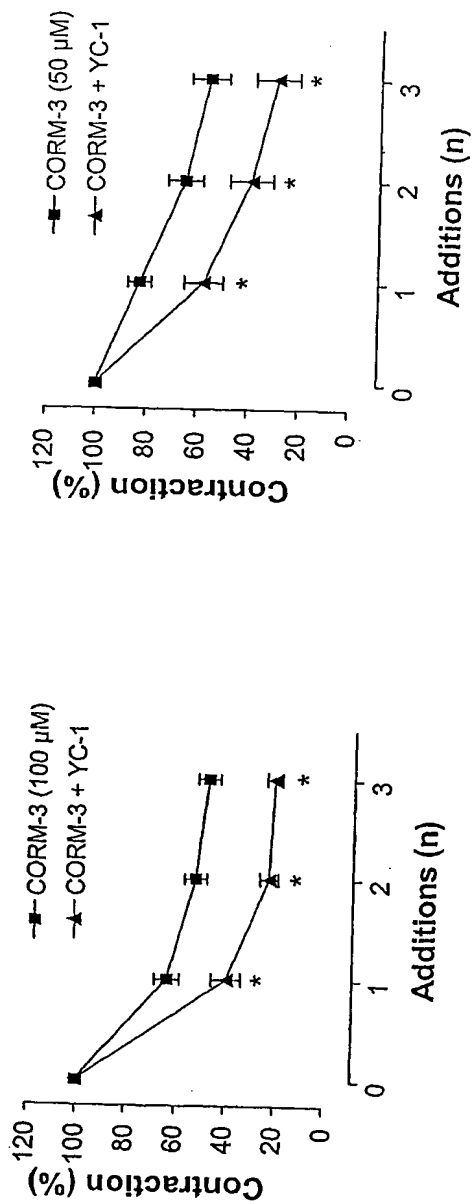


Fig. 7D

Fig. 7C

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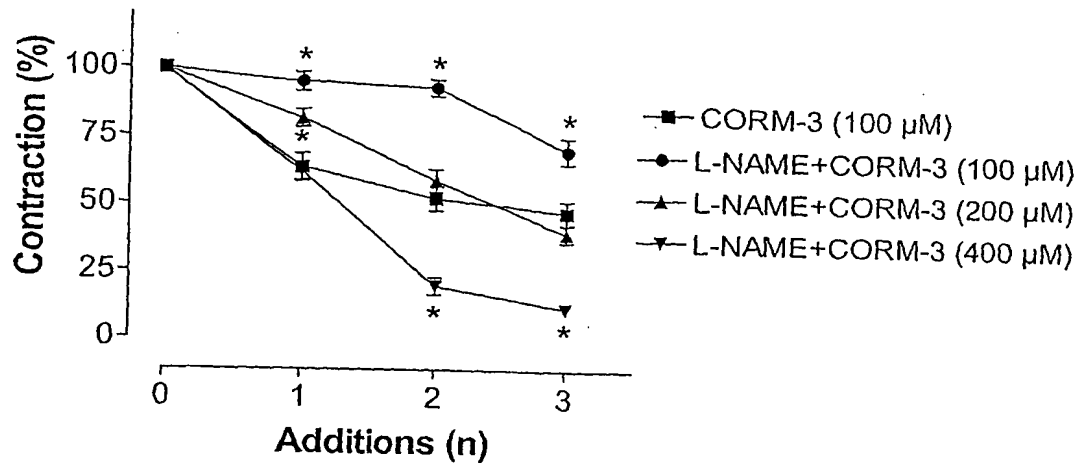


Fig. 8A

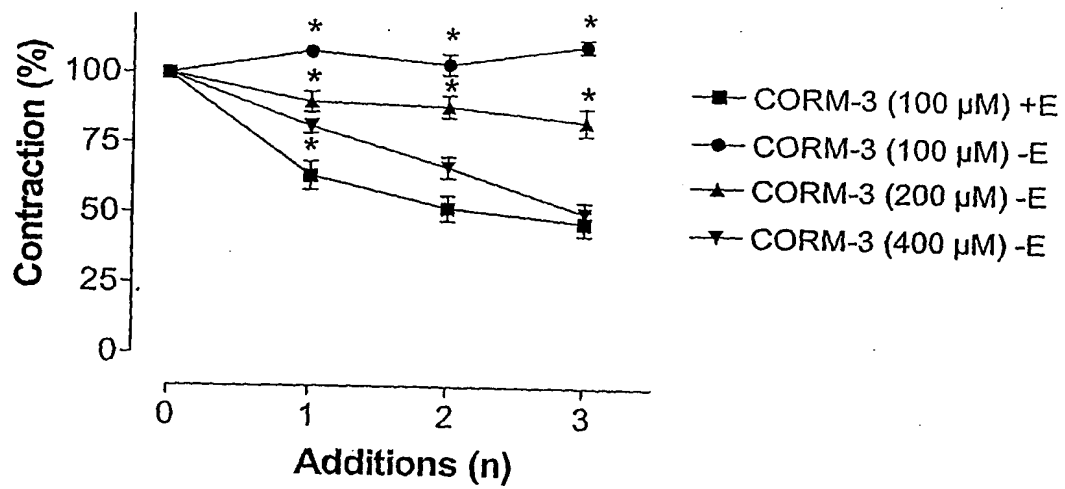


Fig. 8B

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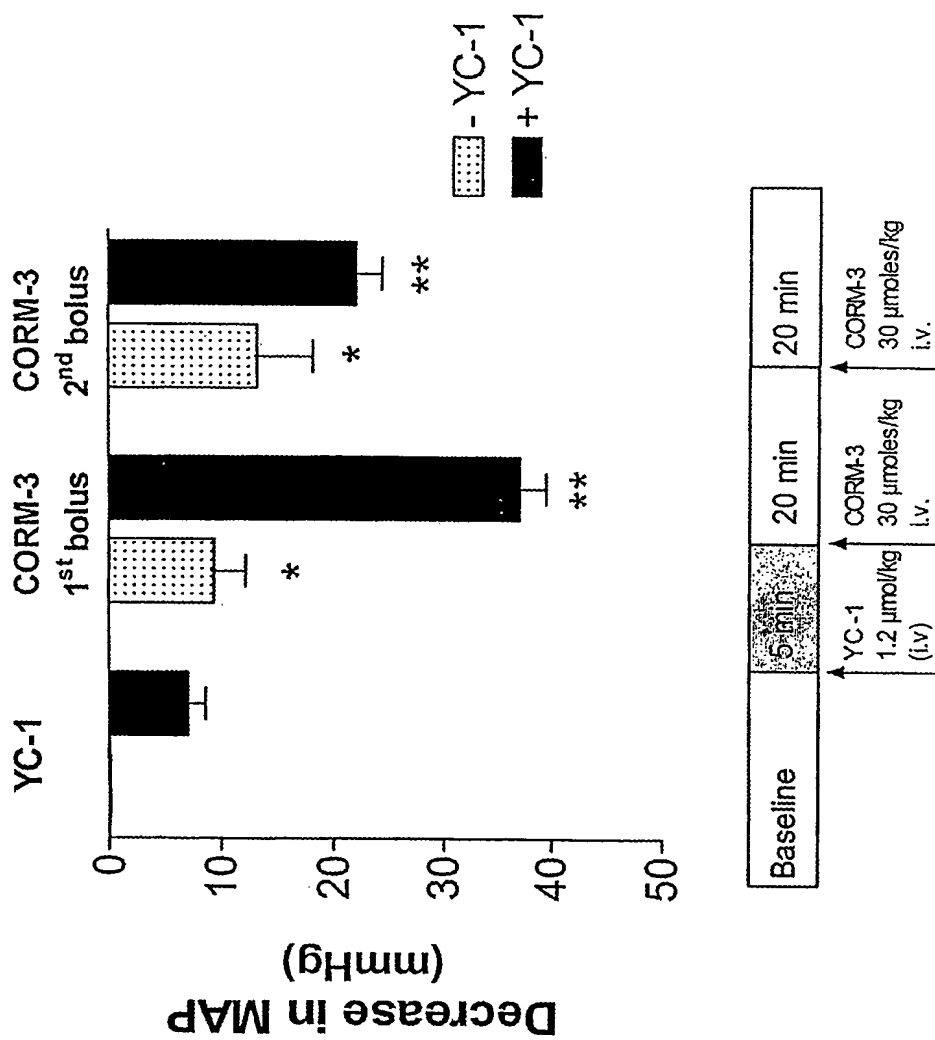


Fig. 9

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/GB 03/05061

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 A61K31/28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal, EMBASE, BIOSIS, MEDLINE, CHEM ABS Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 01 16359 A (UNIV LONDON ; GARTHWAITE GITI (GB); GARTHWAITE JOHN (GB)) 8 March 2001 (2001-03-08) claims	1-35
A	KHARITINOV, V. G. ET AL.: "Kinetics and Equilibria of Soluble Guanylate Cyclase Ligation by CO: Effect of YC-1" BIOCHEMISTRY, vol. 38, 1999, pages 10699-10706, XP002273202 abstract	1-35



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

11 March 2004

Date of mailing of the international search report

24/03/2004

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
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Fax: (+31-70) 340-3016

Authorized officer

Beyss, E

## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

## Continuation of Box I.2

Present claims 1-8, 10-20, 24-32, 34, 35 relate to an extremely large number of possible compounds. Support within the meaning of Article 6 PCT and/or disclosure within the meaning of Article 5 PCT is to be found, however, for only a very small proportion of the compounds claimed. In the present case, the claims so lack support, and the application so lacks disclosure, that a meaningful search over the whole of the claimed scope is impossible. Consequently, the search has been carried out for those parts of the claims which appear to be supported and disclosed, namely those parts relating to the compounds disclosed in claims 9, 21-23, 33.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

# INTERNATIONAL SEARCH REPORT

Intern: application No.  
PCT/GB 03/05061

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
  
Although claims 12-23, 25 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☒ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
  
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.



# INTERNATIONAL SEARCH REPORT

International No

PCT/GB 03/05061

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0116359 A	08-03-2001	AU 6857500 A	26-03-2001
		EP 1220945 A2	10-07-2002
		WO 0116359 A2	08-03-2001
		GB 2370636 A	03-07-2002

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